

## Location and vascular supply of sinus node in human heart

KENNETH R. ANDERSON<sup>1</sup>, S. YEN HO, AND ROBERT H. ANDERSON<sup>2</sup>

*From the Department of Paediatrics, Cardiothoracic Institute, Brompton Hospital, London*

**SUMMARY** The exact location of the sinus node was determined in 25 infant hearts using reconstructive techniques. The sinus node was found to lie on the lateral aspect of the superior cavo-atrial junction in the great majority (22 hearts). In only 3 hearts was it found to straddle the summit of the crest of the right atrial appendage where it is popularly believed to be located. In the majority of instances a single artery supplied the node (in 11 hearts the artery approached posteriorly, and in 10 the artery approached anteriorly), though there was considerable variation in the exact anatomy of the arterial supply. Connections between the sinus node and atrial myocardium were diffuse and abundant but in no instances were tracts of specialised cells observed leaving the node and traversing any distance through the atrial wall. These findings are relevant to the sinus node dysfunction that may follow cardiac surgical procedures.

Increased interest in disorders of sinus node function, together with the known vulnerability of the node to surgical injury, have reawakened the thirst for knowledge of its anatomy, histology, normal ageing changes, and vascular supply. Despite the wealth of published reports describing the anatomy of the node, its exact location is not well appreciated. Though originally described in a lateral position in the sulcus terminalis by Keith and Flack (1907), a finding endorsed by Koch (1909) and several subsequent investigators (James, 1961; Truex *et al.*, 1967; Lev and Bharati, 1974, 1977; Anderson *et al.*, 1978), Blair and Davies (1935), Davies (1942), and Hudson (1965), described the node as straddling the crest of the right atrial appendage at its junction with the superior vena cava. The precise course of the artery of supply to the node is also not fully understood, James (1961) indicating that it may approach the node in either a clockwise or counter-clockwise fashion relative to the superior vena cava, while Hutchinson (1978) has described a caval circle of arteries in the environs of the node.

<sup>1</sup>National Heart Foundation of New Zealand Fellow in Cardiovascular Pathology. Present address: Department of Pathology, University of Otago Medical School, Dunedin, New Zealand.

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These possible variations are of major significance in postoperative sinus node dysfunction, a problem compounded by controversies surrounding the substrates for internodal atrial conduction (James, 1963; El Said *et al.*, 1972; Isaacson *et al.*, 1972; Janse and Anderson, 1974). With all these considerations in mind, we have attempted to define accurately the anatomy, disposition, connections, and vascular supply of the sinuatrial node by reconstructions from histological sections of 25 normal human infant hearts.

### Subjects and methods

The anatomically normal hearts were from infants less than 1 year of age. Infant hearts were used because the smaller tissue block is easier to handle and the borders of the node can be more accurately defined. In each heart the superior vena cava and adjacent atrium were excised. This block was carefully embedded and serially sectioned with the rotary microtome set at 10  $\mu$ . Every 25th section was mounted and stained with the Masson trichrome method. Extra sections were prepared as required. In 8 instances the block was sectioned in a frontal plane (anteroposterior) and in 17 instances in a transverse plane (superoinferior) (Fig. 1). The anatomy of the sinus node and its arterial blood supply was then reconstructed on graph paper. With the coronal method of sectioning,

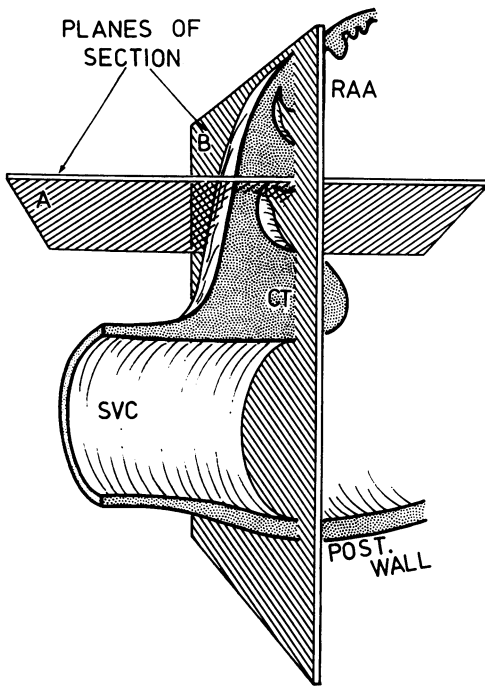


Fig. 1 Diagram to illustrate the two methods of sectioning the tissue block for histological examination of the sinus node. (A) Frontal plane sectioning (8 hearts). (B) Transverse plane sectioning (17 hearts). SVC, superior vena cava; RAA, right atrial appendage; CT, crista terminalis.

reconstruction was carried out with the aid of a calibrated measuring eye piece (Fig. 2).

## Results

The sinus node was easily identified in all the hearts studied. Though in several there was venous congestion of the node and adjacent atrial myocardium, no other pathology was recognised.

### LOCATION OF NODE

In 22 hearts the sinus node lay in the groove between the right atrial appendage and the lateral atrial wall (sulcus terminalis) (Fig. 3). The long axis of the node was parallel to the sulcus terminalis, with the anterosuperior 'head' situated between 2 and 4 mm below the crest of the right atrial appendage. The posteroinferior 'tail' was up to 10 mm below this level. The anterosuperior 'head' was subepicardial and the posteroinferior 'tail' predominantly intramyocardial with the tip of the 'tail' contacting subendocardial tissue. In 3 hearts the sinus node straddled the crest of the atrial appendage so that the anterosuperior 'head' was to

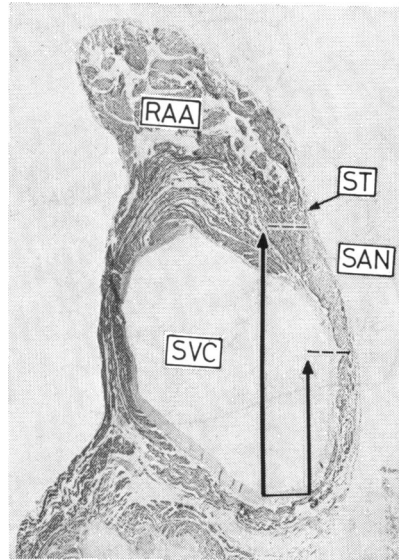


Fig. 2 A transverse section of the cavoatrial junction showing the sinus node. Examples of some of the measuring lines used to reconstruct the anatomy of the region are superimposed. SVC, superior vena cava; RAA, right atrial appendage; SAN, sinuatrial node; ST, sulcus terminalis. ( $\times 7$ )

the left of the crest and the 'body' and 'tail' were to the right of the crest (Fig. 4). In these hearts the posteroinferior 'tail' was situated at a higher level than in the other 22 hearts.

### DIMENSIONS OF NODE

The node measured between 4 and 6 mm in length, 2 and 3 mm in width, and less than 1 mm in thickness. These measurements did not include the transitional zone around the node (*vide infra*).

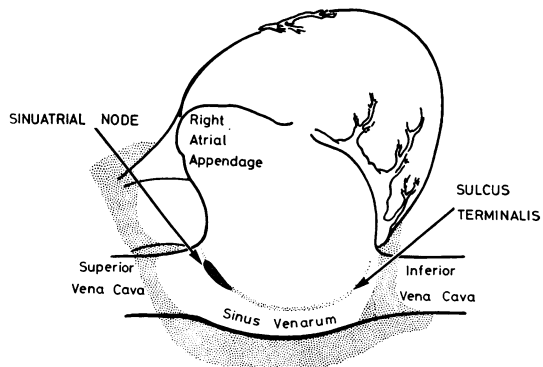


Fig. 3 Diagram of a heart viewed from the right side of the chest showing the location of the sinus node in 22 of the 25 hearts studied.

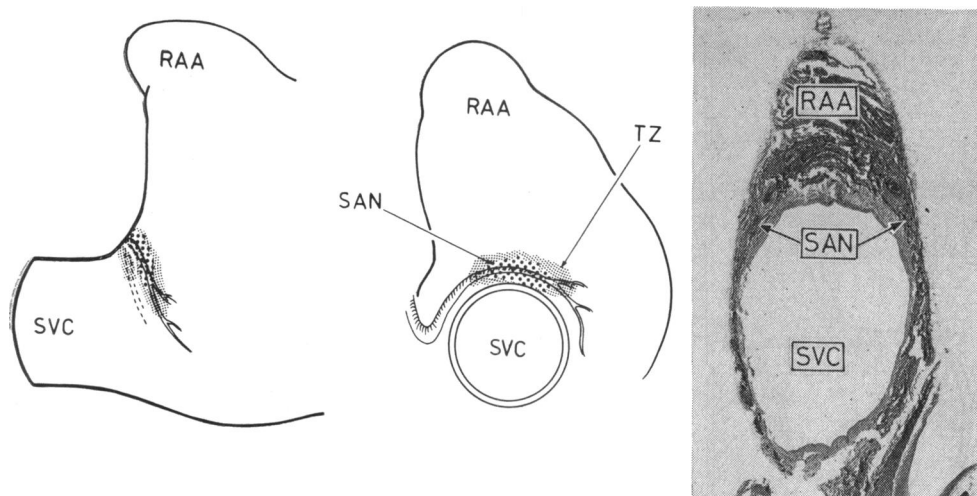


Fig. 4 The location of the sinus node in 3 of the 25 hearts studied. On the left is a diagram of the cavoatrial region viewed from the right chest. In the centre is a similar diagram but viewed from above the heart. On the right is a photomicrograph ( $\times 7$ ) of a section through the atriocaval junction which shows nodal tissue associated with the sinuatrial node artery. This is situated both lateral and medial to the mid-line crest of the right atrial appendage where it joins the superior vena cava. RAA, right atrial appendage; SVC, superior vena cava; SAN, sinuatrial node; TZ, transitional zone of the node.

#### HISTOLOGY AND CONNECTIONS OF NODE

The topography of the nodes showed considerable variation, with tongues of nodal tissue extending centrifugally outwards to accompany branches of the sinus node artery. These tongues did not become connections between nodal and atrial myocardium for they remained surrounded by connective tissue. Cell to cell contact between sinus node specialised cells and atrial myocardial cells was infrequently identified with certainty, though closely approximating cells were often observed. This was seen particularly where the large bulk of muscle making up to the crista terminalis was related to the node and here a transitional zone was present. More posteriorly, towards the tail of the node, nodal cells closely approximated the more sparsely muscularised posterolateral atrial wall. Frequently a small bundle of nodal cells extended in the epicardium some distance posterior to the node.

The infant sinus nodes were predominantly composed of syncytial cells which were randomly orientated and irregularly interlacing. The major bulk of each node was made up of specialised cells but there was always a background framework of fine collagen and reticulin fibres.

#### ARTERIAL BLOOD SUPPLY

In 11 hearts (44%) the sinus node artery approached the node from the posterior aspect, circling the

posterior atrial wall in an anticlockwise direction (looking down at the heart from above). When turning on to the lateral atrial wall the artery was considerably inferior to the level of the summit of the crest of the right atrial appendage and the artery coursed superiorly as well as anteriorly to reach the 'tail' of the node (Fig. 5A). In 10 hearts (40%) the artery approached the node from the anterior aspect, circling clockwise (looking down at the heart from above), and arching over the crest of the right atrial appendage. On reaching the lateral atrial wall the artery coursed postero-inferiorly to reach the 'head' of the node (Fig. 5B). In 4 hearts (16%) arteries approached both anteriorly and posteriorly and anastomosed within the substance of the node (Fig. 5C).

In 8 hearts (32%) the artery ramified and terminated in the node. In 13 hearts (52%) the artery coursed through the centre of the node continuing distally to the atrial wall. In 2 hearts (8%) the major artery skirted the node and in a further 2 hearts (8%) no dominant artery was present.

#### VENOUS BLOOD SUPPLY

Veins did not accompany the sinus node artery but in several instances small venules from the node were observed draining directly into the right atrium adjacent to the node.

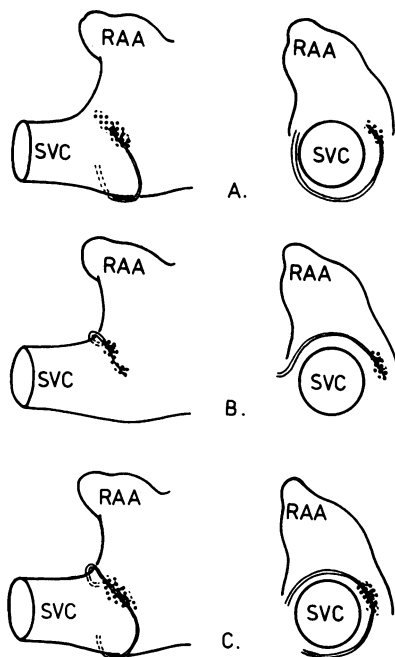


Fig. 5 Diagrams to illustrate the variable arterial supply of the sinus node. Those on the left of the Fig. are as viewed from the right and those on the right of the Fig. are as viewed from above the heart. (A) posterior approaching artery (11 hearts). (B) anterior approaching artery (10 hearts). (C) anastomotic ring (4 hearts). SVC, superior vena cava; RAA, right atrial appendage.

## Discussion

Our findings regarding the disposition of the sinuatrial node are very much an endorsement of the initial description of Keith and Flack (1907), and the subsequent studies of Koch (1909), and others. In the majority of hearts, therefore, the node was a lateral structure relative to the superior cavo-atrial junction, a finding in contrast to those of Blair and Davies (1935), Davies (1942), and Hudson (1965), who described the sinuatrial node as a structure slung over the crest of the right atrial appendage. However, this variation was observed in 3 of the 25 (12%) normal hearts. With the exception of these cases we found the infant sinus node to be remarkably constant in position. It lies on the lateral right atrial wall with its long axis in the sulcus terminalis, and its anterior 'head' superior to its posterior 'tail'. It is unlikely that the location should be any different in adults.

Variations in the description of the precise position of the sinuatrial node by various authors (Taussig, 1931; Blair and Davies, 1935; Hudson,

1965; James, 1961; Truex *et al.*, 1967; Lev and Bharati, 1974; Anderson *et al.*, 1978), may in part be the result of the limited individual variation in nodal position but seems more likely to be attributable to the method of sectioning the tissue block. When the block is sectioned in a frontal plane, or by the method advocated by Hudson (1965), the sections obtained do not contain an identifiable reference point to which the node can be related. The transverse method of sectioning has the distinct advantage that the relatively straight posterior caval and atrial walls are seen in every section and provide a constant reference base for morphometric reconstruction.

The topography of the node is also variable, with small tongues of nodal tissue extending outwards to accompany branches of the main artery. Despite this, the basic shape of the node is constant. It is pointed at each end of the long axis and the long axis is two to three times the dimension of the width. It is flattened against the atrial wall but the inferior margin is thicker, so that in cross-section the node appears triangular, with the apex of the triangle directed upwards.

Close encounters between specialised nodal cells and atrial myocardial cells were seen frequently, particularly in the crista terminalis and posterolateral atrial wall. The histology of these regions is distinct, resembling neither the node itself nor the atrial musculature, and the term transitional zone is warranted. Definite cell to cell contacts between specialised cells and atrial myocytes can also be observed, but in no instances have we seen discrete tracts of specialised cells leaving the node and traversing any distance into the atrial myocardium. The latter point is of importance in the sinus node dysfunction that may occur after cardiac surgery, for it has been suggested that this is often the result of interruption of atrial internodal pathways (Isaacson *et al.*, 1972). This seems unlikely in the presence of relatively abundant connections between node and atrium and in the absence of distinct pathways (Janse and Anderson, 1974). In our view it is far more likely that postoperative sinus node dysfunction is the result of either direct trauma to the node or interruption of the arterial blood supply to the node.

An increase in connective tissue in the sinuatrial node is a normal change with age (Lev, 1954), though at any age the quantity of collagen is variable (James, 1961, 1977). The functional significance of this ageing phenomenon is questionable, but Evans and Shaw (1977) found distinct fibrosis of the node in some patients with chronic sinuatrial node disease. The infant nodes in this study all had an identifiable reticulin and fine

collagen framework, in contrast to the findings of James (1977). None the less, the bulk of the node was composed of specialised cells. The dimensions were approximately one-half those previously reported for adult nodes (James, 1961; Merideth and Titus, 1968). It is our impression that the increased size of the adult sinuatrial node can be attributed to its increased connective tissue component with corresponding decrease in the proportion of nodal specialised cells per unit area of node, though this observation requires quantitative documentation.

The sinuatrial node artery may approach posteriorly, anteriorly, or less commonly from both directions. We concur with James (1961) that there is considerable variation in the size of the artery and its method of ramification within the node. We do not agree with Hutchinson (1978) that the sinuatrial node artery in the majority of hearts is part of an anastomotic ring around the atriocaval junction and we found this to be the exception rather than the rule. It is possible that the development of an anastomotic ring is an ageing feature as the majority of Hutchinson's subjects were in the fifth and sixth decades and ours were infants.

Thus our findings show that on external examination of the heart, the location of the sinuatrial node can be predicted using the summit of the crest of the right atrial appendage and the sulcus terminalis as landmarks, the node in the majority of cases being a lateral structure. From within the right atrial chamber the crista terminalis, which is the internal expression of the sulcus terminalis, is a satisfactory landmark. The location of the artery supplying the node is less predictable but if surgical injury is to be prevented with certainty, then the entire atriocaval junction should be avoided.

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Requests for reprints to Dr R. H. Anderson, Department of Paediatrics, Cardiothoracic Institute, Brompton Hospital, Fulham Road, London SW3 6HP.